Analysis of Wood Anatomy Characteristics by Fast Fourier Transfer Image Analysis[1]

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Abstract Fast Fourier Transfer Image Processing was widely applied to the analysis of wood anatomy structure in recent years. The cells in the wood transverse section have obviously periodicity and regularity. FFT power spectral patterns can extract the periodic characteristics so that they can be compared, identified and classified quantitatively. This paper summarizes the application of FFT image analysis in wood science and the general way to study wood anatomy by FFT.

Keywords: Fast Fourier Transfer (FFT), Image analysis, Periodicity, Wood anatomy characteristics

Application of FFT

Computer image processing is a new technology which merges optics, electronics, computer and pattern recognition. It has been applied widely in the research of wood science because it has the properties of high measuring speed, high precision and non contact measuring. As the developing of computer image processing, Fast Fourier Transfer (FFT) Image Analysis has been applied gradually. FFT is a technique in which the gray change is a processing factor. It can transfer the dispersed signal into periodic function so that it's very useful in the image processing of natural product which has the periodic characteristics. More and more researchers have used this way to deal with wood anatomy characteristic since 1990s.

FFT can be applied to analyze wood cells arrangement (Fujita M., 1990). Using polar coordinate to calculate the gray levels in each direction and analyze the angular distribution function of the power spectral patterns. Huang YS (1990) used FFT to estimate the roughness of wood sandness surface. Fujita M., (1991) used a two-dimensional Fourier transform which was composes of both processing of analogical method (OFT) with a optical system and FFT system to analyze the cell arrangements and sizes quantitatively. Matanabe U. (1995) modeled the cell shapes in both the wet condition and the oven-dry condition by FFT, and the models in both conditions were used to express the shrinkage deformation of the wood cell. The result of the study indicate that the anisotropic shrinkage on the transverse surface of wood originates primarily from that of the cell and secondarily from the other factors such as tree rings. Fujita M. (1995) applied the FFT image analysis procedure to the study of 32 species of Japanese hardwoods in order to characterize their vessel distributions. It was suggested that when the power spectral patterns of FFT were characterized both qualitatively and quantitatively, the automatic identification of hardwoods might be possible. But the quantitative analyze didn't been shown. Xiuming Diao *et al* (1995) used this quantitative analysis method to detect the periodicity of cell arrangements and cell shape in the transverse sections of softwood. According to the angular distribution function of gray level of Fourier power spectrum image, the properties of periodic arrangement among the species were compared quantitatively.

Image processing has been widely used in measuring the size, shape, the ratio of wall and wall thickness of cells. But few papers dealt with the periodicity and orientation of cells, especially in China. Wood is a kind of nature product that has periodicity in cells arrangement, direction and distribution homogeneity of cell diameters which is an important property in the wood anatomy research. FFT power spectral patterns can extract the periodic characteristics so that they can be compared, identified and classified quantitatively. Fourier Transfer Image Analysis has been proved to be a very powerful technique for the quantification of wood structures, being based on mathematical techniques (Hata *et al.* 1989). However, there were few papers dealing with the power spectra patterns by FFT image analysis. So it's important to make a systematic

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study on the patterns of FFT.

Analysis Methods

Construction of the computer analysis system were shown in reference 6. A collimated plane of light or a laser is directed the samples slide, then a optics system that consists of lens focuses the image of surface on to the objective of the CCD camera, the CCD captures the image of the wood structure , and a frame grabber board digitizes the image. After preliminary processing, the digitized image is filtered transmitted into a microcomputer. through the use of the software algorithms in the applied software library, the computer filters the noise and outside space influence, and then the image is binarized. The threshold used in binarizing operation should be determined by a lot of experiment. The image after binarized is simplified to dot maps and net maps.

The dot maps and net maps are processed by the image software with FFT analysis function and then the power spectral patterns (PSPs) can be got.

Analysis of PSPs

There are a lot of useful information in the PSPs which were transferred from dot maps.

The amount of frequency and the direction of streaks have the information of cell arrangement.

Frequency and direction analysis of PSPs

Frequencies were divided into the low, medium and high components. The low-frequency components which correspond to big size pattern, are related to the evenness of dot distribution all over the annual rings. Generally in the diffuse-porous woods, the components is supposed to be negligible. While the ring-porous woods and radial-porous woods which have uneven distribution of vessels are expected to show peculiar powers on the lower-frequency components. The medium-frequency component is related to the style of vessel dispersion, especially in the diffuse-porous woods. The presence of oblique arrangement of vessels can also be detected by these powers. The high-frequency can be used to detect the occurrence of pore clusters.

The equatorial and meridian streaks can be observed on many of the PSPs. When the radial direction of original wood section are input to be vertical, the equatorial streaks are derived from the regularity of dots in the radial direction, while the meridian streaks are related to the tangential arrangement of dots. The equatorial streaks are derived from a straight arrangement of vessels along the radial files which is usual in softwoods tracheids. These streaks are clearly presented in diffuse-porous woods having small-sized vessels. Power distribution along the streaks is affected by the regularity of tangential intervals between neighboring radial files. Ray excluding vessels make radial bands where vessels are absent. In Fourier Transfer Image Analysis, the occurrence and absence of picture elements have similar value with another one, because they are on the top and bottom of the wave forms. Cell arrangement other than vessels could be evaluated by the vessel dot maps. For instance, using the outer peak radius, the periodic distance between neighboring radial files, that is, the tangential width of the fusiform initial can be calculated. On the other hand, the inner peaks tell us that rays have a periodicity and the intervals can be estimated by the peak radial. The occurrence of meridian streaks are considered to originate from two sources which are the existence and absence of a tangential arrangement of vessels.

Measurement of tracheid diameters

In the dot map, the distances among the dots were regarded as the tracheid diameters in the radial and tangential direction. Therefore, the periods calculated according to the frequencies having the large peaks along the angles of about 0° and 90°in the PSPs corresponds to the tangential and radial diameters, respectively. The tracheid diameters could be measured effectively by means of frequency distribution functions.

Extracting of the angles of cell walls

The high frequency domain in the image of PSPs from a net map showed the information about the arrangement angles of cell walls. If the angle distribution function are known, the angles which there are the peaks with the high gray level are arranges as the most frequent angles of cell walls.

Based on the parameters obtained about the periodicity arrangements and the arrangement angles of cell walls, the modeling of tracheids can be developed.

Evaluation of tracheid arrangement with the angular distribution function

The PSPs were analyzed by polar coordinate. The angular distribution function was calculated by gray sum in each θ direction. According to the θ and peak height

the direction of cell arrangement can be described. For instance, when $\theta = \alpha$, there is curve peak, cells are trend to arrange in $\alpha \pm 90°$.

The PSPs of sugi is shown in Fig. 1. The angular distribution function after polar transfer is shown in Fig. 2 in which the vertical axes represent the ratios between the gray sum in the given angle and the one in the angle from 0° and 360°. There are the sharp peaks in the angles of about 0° and 180°. They show the tracheid arrangements as the form of radial files, that is, the strong periodicity along the tangential direction in the original image. Moreover, the small peaks in the angles of 50° and 130° show that there are the weak periodic arrangements in the oblique directions. There exist differences in the tracheid arrangements in the tangential and the oblique direction among species. Therefore we can extract the two-dimensional arrangement characteristics of cells quantitatively according to the angle distribution function.

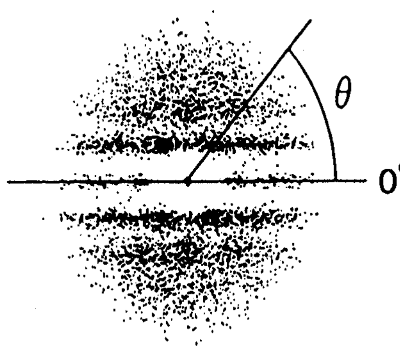

Fig. 1 FFT Power spectral pattern of dot map

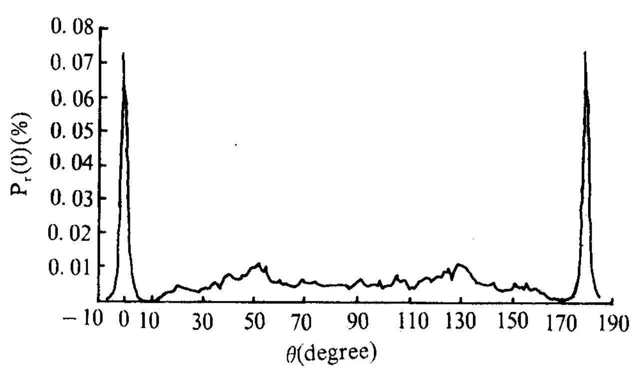

Fig. 2 Angular distribution function of dot map

Fujita M. (1991) and Xiuming Diao (1995)studied sugi using this methods. Their results were showing no differences. FFT is a effective method to study the periodicity of wood transverse anatomy characteristics.

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